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(56) Documents Cited
GB 2003234 A EP 0436513 A1 EP 0399437 A2
EP 0065888 A1 EP 0049662 A1 EP 0037786 A2
US 4368618 A

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(54) Fuel control system for a gas turbine engine

(57) A fuel control system for a gas turbine engine, comprises a main metering valve 18 for controlling fuel supply to the engine during a first mode of operation. A back-up metering valve 3 is provided in series with the main metering valve 18 for controlling fuel supply to the engine during a second mode of operation. The back-up metering valve 3 is arranged to track the main metering valve 18 during the first mode of operation. A changeover means 16 is provided for bypassing the back-up metering valve 3 during the first mode of operation and for connecting the back-up metering valve 3 with the main metering valve 18 during the second mode of operation.

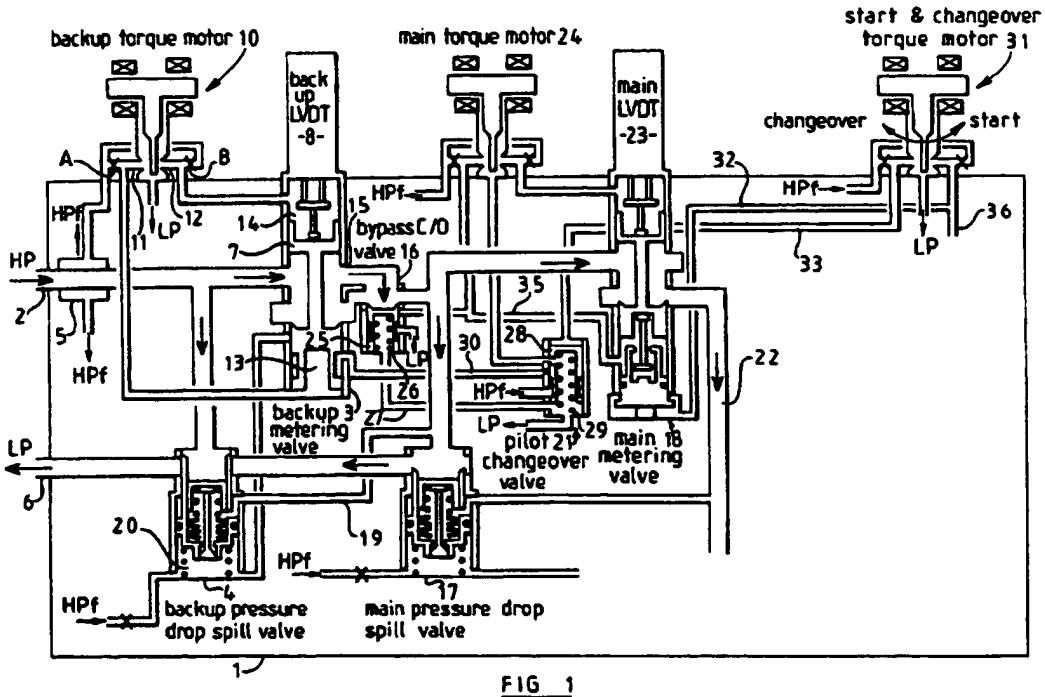

FIG 1

At least ne drawing originally filed was inf rmal and the print reproduced here is taken fr m a later filed formal copy.

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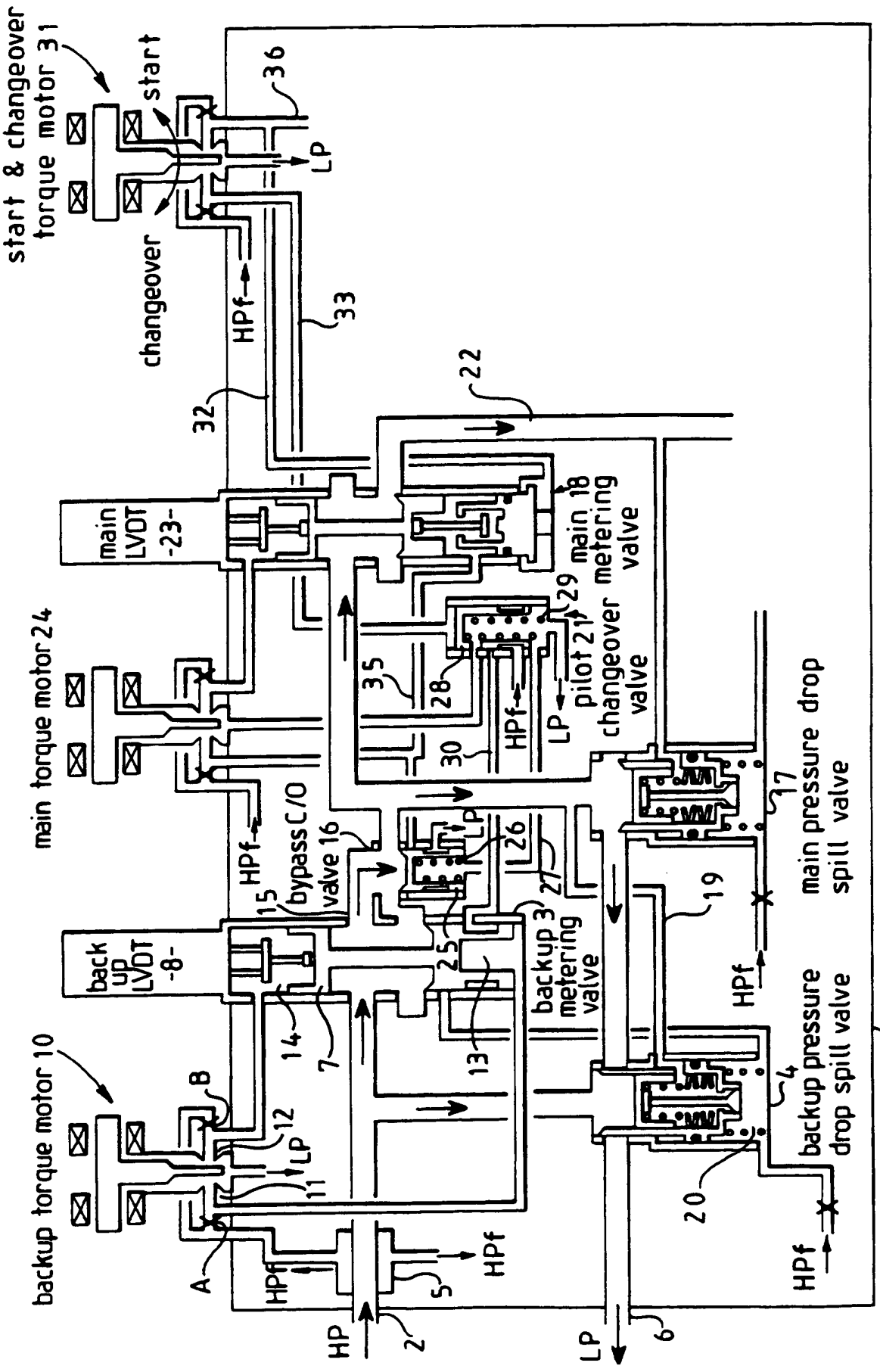
start & changeover torque motor 31
start
changeover
36
LP
HPf
33
32
22
main LVDT -23-
main metering valve 18
main torque motor 24
29
pilot 21
changeover valve
35
28
30
HPf
LP
bypass C/O valve 16
15
HPf
LP
26
27
17
main pressure drop spill valve
back up LVDT -8-
backup metering valve 3
25
19
HPf
14
7
13
backup torque motor 10
B
12
LP
11
A
HPf
HPf
5
HP
2
LP
6
4
backup pressure drop spill valve
20
HPf
1

FIG 1

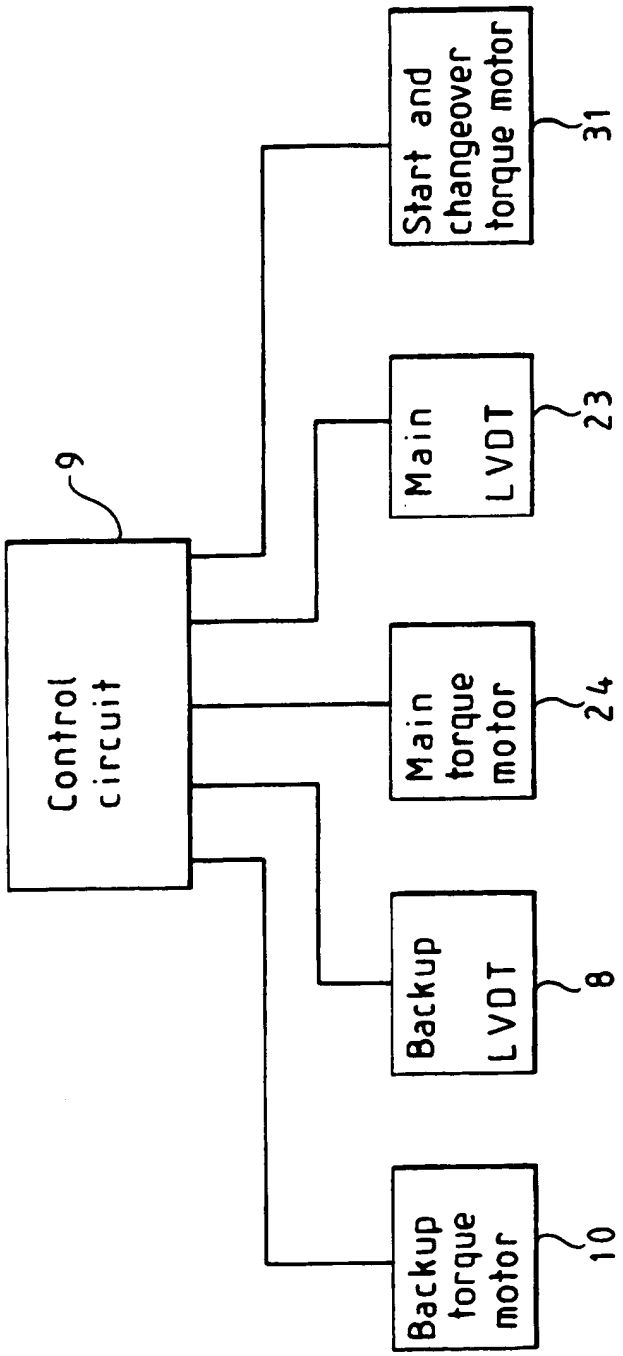
Control circuit
9
Start and changeover torque motor
31
Main LVDT
23
Main torque motor
24
Backup LVDT
8
Backup torque motor
10

FIG 2

FUEL CONTROL SYSTEM FOR A GAS TURBINE ENGINE

The present invention relates to a fuel control system for a gas turbine engine.

EPO 436513 discloses a fuel control system for a gas turbine engine of a helicopter. The system includes a main metering valve which controls the supply of fuel to one or more gas turbine engines driving the helicopter rotor. A back up metering valve in series with the main metering valve is also provided for taking over control of the supply of fuel in the event of a fault or failure of the main metering valve or any of its associated components. In order to provide a smooth transition from normal operation using the main metering valve and back up operation using the back up metering valve, the position of the main metering valve is 'frozen' while the back up metering valve is controlled so as to provide the demanded rate of supply of fuel. Once the back up valve has effectively taken over control of fuel supply, the main metering valve is opened fully. This arrangement therefore provides smooth or 'bumpless' change over from normal operation to back up operation, for instance permitting manual control of engine fuel supply by the pilot as opposed to automatic control by the control system. However, the speed of change over from normal operation to back up operation is limited by the delay caused by moving the back up metering valve from its stand by position to the required position for taking over control of fuel supply.

According to the invention, there is provided a fuel control system for a gas turbine engine, comprising:

a main metering valve for controlling fuel supply to the engine during a first mode of operation;

a back up metering valve in series with the main metering valve for controlling fuel supply to the engine during a second mode of operation, the back up metering valve being arranged to track the main metering valve during the first mode of operation; and

change over means for bypassing the back up metering valve during the first mode of operation and for connecting the back up metering valve with the main metering valve during the second mode of operation.

Preferably the change over means is arranged to inhibit the main metering valve from changing the supply of fuel during a transition from the first mode of operation to the second mode of operation.

Preferably the change over means is arranged to cause the main metering valve to open fully after the back up metering valve has been connected in series during the second mode of operation.

Preferably, during a transition from the second mode of operation to the first mode of operation, the change over means is arranged to cause the main metering valve to adopt the same setting as the back up metering valve before bypassing the back up metering valve.

It is thus possible to provide a fuel control system which may be used to control the supply of fuel to a gas turbine engine, for instance for aerospace applications, in which a bumpless or smooth change over between normal operation and back up operation is achieved very

rapidly. During the first mode of operation, which preferably corresponds to normal operation, the back up metering valve tracks the operation of the main metering valve so that, when operation is changed to the second mode corresponding to back up operation, the back up metering valve is in the correct position. Smooth transition may therefore be made with a minimum delay. Normal operation may correspond to automatic control of fuelling or control in accordance with an engine control or management system using data processing to provide optimised fuel control. The back up mode may, for instance, be less sophisticated electronics control so as to maintain control in the event of a fault or failure in the engine control system, the main metering valve, or any associated component.

Any return from the back up mode to the normal mode of operation can be achieved by a bumpless change over. However, return to normal operation does not have to be achieved as quickly as possible so that a transition which is slower than that for change over to back up operation can be provided.

The present invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a fuel control system for a gas turbine engine constituting an embodiment of the invention; and

Figure 2 is a block schematic diagram illustrating a control system for the fuel control system of Figure 1.

Figure 1 illustrates an enclosure 1 which contains most of the parts of a fuel control system for a gas turbine engine, for instance for use in an aircraft. High pressure (HP) fuel is supplied through an inlet 2 to a back up metering valve 3 and to a back up pressure drop spill valve 4. The high pressure fuel is filtered by a filter 5 and the high pressure filtered (HPf) fuel is supplied to various parts of the fuel control system. An outlet 6 returns low pressure (LP) fuel from various parts of the fuel control system to the inlet of a fuel pump which supplies the high pressure fuel.

The back up metering valve 3 comprises a valve member 7 whose position is measured by a back up linear variable displacement transducer (LVDT) 8. Position signals from the LVDT 8 are supplied to a control circuit 9 which controls a back up torque motor 10 which controls the position of the valve member 7. The back up torque motor 10 comprises windings associated with a permanently magnetised armature which is pivotable from a normal position as illustrated in Figure 1 to left and right positions in which it shuts off orifices 11 and 12, respectively. High pressure filtered fuel is supplied via restrictors A and B to the orifices 11 and 12 and to lower and upper servo chambers 13 and 14, respectively, on opposite sides of the valve member 7. With the armature in the normal position illustrated in Figure 1, the orifices 11 and 12 vent the high pressure filtered fuel to the low pressure outlet 6. The pressures in the servo chambers 13 and 14 are therefore equal and the valve member 7 is held stationary.

When the armature of the torque motor 10 is controlled so as to shut off the orifice 11, venting of fuel through this orifice is prevented so that the pressure of fuel in the servo chamber 13 is increased whereas that in the

servo chamber 14 remains the same. Thus, the valve member 7 is moved upwardly so as to reduce the metering orifice of the back up metering valve 3. Similarly, when the orifice 12 is closed by the armature of the torque motor 10, the valve member 7 is forced downwardly so as to increase the opening of the metering orifice of the back up metering valve 3.

The back up metering valve 3 has a bypass outlet 15 through which high pressure fuel flows to a bypass change over valve 16. During normal operation of the fuel control system, the valve 16 causes the high pressure fuel effectively to bypass the metering orifice of the back up metering valve 3, the high pressure fuel then being supplied to a main pressure drop spill valve 17 and a main metering valve 18. For back up operation, the bypass change over valve 16 shuts off the bypass outlet 15 but opens the main metering orifice so that the back up metering valve 3 can control the rate of supply of fuel. The back up pressure drop spill valve 4 is connected via a pipe 19 to the outlet of the back up metering valve 3 and has a servo chamber 20 which receives high pressure filtered fuel and which is connectable via orifices and chambers in the back up metering valve 3 to a pilot change over valve 21 when the valve member 7 is in the fully closed position. The back up pressure drop spill valve 4 operates in known way during back up operation of the fuel control system so as to maintain a substantially constant pressure drop across the metering orifice of the back up metering valve 3. The rate of flow of fuel is therefore proportional to the opening of the metering orifice of the back up metering valve 3.

During normal operation, the back up pressure drop spill valve tries to meter a flow corresponding to the back up metering valve and bypass in

parallel. This is a higher flow than that corresponding to the main metering valve position and the back up spill valve therefore fully closes.

The back up LVDT 8 and the back up torque motor 10 cooperate with part of the control circuit 9 so as to form a servo control loop for controlling metering by the back up metering valve 3 of fuel during back up operation.

The main pressure drop spill valve 17 is connected to the outlet 22 of the main metering valve 18 and similarly serves to provide a constant pressure drop across the metering orifice of the valve 18 during normal operation so that the rate of fuel supply by the main metering valve 18 is proportional to the opening of the metering orifice. The main metering valve 18 is provided with a main LVDT 23 and a main torque motor 24 which are substantially identical to and operate in the same way as the back up LVDT 8 and the back up torque motor 10. Fuel from the outlet 22 passes to other components of the fuel control system (not shown), such as a pressure raising and shut off valve, before being supplied to the gas turbine engine.

The by pass change over valve 16 has a valve member 25 which is movable from the position shown in Figure 1 during normal operation to a raised position during back up operation. The valve member 25 is urged upwardly by a spring 26 within a servo chamber which is connected by a pipe 27 to the pilot change over valve 21. The valve member 25 has an annular recess which shuts off connection between the low pressure outlet and the main torque motor 24 during normal operation and which interconnects these during back up operation.

The pilot change over valve 21 has a valve member 28 which is in the position shown in Figure 1 during normal operation and which is urged downwardly against a spring 29 during back up operation. The servo return outlet from the main torque motor 24 is connected via orifices in the valve member and valve body to the low pressure outlet during normal operation. During back up operation, the valve member 28 seals the servo return outlet from the main torque motor 24. During back up operation, the orifice in the valve member 28 connects a pipe 30 from the back up metering valve 3 to the low pressure outlet. During normal operation, the pipe 27 is vented through the pilot change over valve 21 to the low pressure outlet whereas, during back up operation, the pipe 27 is connected via an annular recess in the valve member 28 to the high pressure fuel.

A start and change over torque motor 31 cooperates with orifices and the high pressure filtered fuel supply to control fuel pressures in pipe 32 during engine starting and pipe 33 to change from normal to back up operation. The motor 31 is controlled by the control circuit 9.

During normal operation, the various valves are in the positions shown in Figure 1. In particular, the start and change over torque motor 31 uncovers both orifices, the pilot change over valve member 28 is in its upper position, and the bypass change over valve member 25 is in its lower position. High pressure fuel thus passes through the back up metering valve 3 via the outlet 15 and through the bypass change over valve 16 to the main metering valve 18. There is therefore insufficient pressure drop across the back up metering valve 3 to open the back up pressure drop spill valve 4 even if the back up metering valve 3 were to fail with the metering orifice fully closed. Further, the pilot change over

valve 21 shuts off the pipe 30 so that the back up pressure drop spill valve 4 cannot open if the back up metering valve 3 fails with the metering orifice closed.

In order to change over from the normal mode to the back up mode, the start and change over torque motor 31 is energised so as to shut off the orifice connected to the pipe 33. This causes the valve member 28 to be driven rapidly to its lower position corresponding to back up operation. The valve member 28 thus shuts off the connection from the main torque motor servo return outlet to the low pressure outlet, for instance in less than 0.05 seconds, so that the main metering valve 18 stops moving, both servo pressures now being at the pressure of the high pressure filtered fuel regardless of the position of the main torque motor 24. Any slow drifting of position of the main metering valve 18 is of no consequence as the position of the valve member will change minimally during the transition to back up mode.

The pilot change over valve 21 then connects the bypass change over valve servo chamber to the high pressure filtered fuel via the pipe 27 so that the valve member 25 is driven upwardly and closes the bypass orifice 15, for instance in less than 0.3 seconds. The back up metering valve 3 is controlled by the control circuit 9, during normal operation, so that it tracks the main metering valve 18 and is therefore already in the correct position to assume fuel control. The back up pressure drop spill valve 4 is now able to operate so as to control the pressure drop across the metering orifice of the back up metering valve 3.

As the back up metering valve bypass orifice shuts, the bypass change over valve 16 connects the lower servo chamber of the main metering

valve via a pipe 35 to the low pressure outlet, so that the relatively high pressure in the upper servo chamber of the main metering valve 18 causes the main metering valve 18 to be driven fully open. The pressure drop across the main metering valve decreases as it opens so that the main pressure drop spill valve 17 is driven closed by servo pressure and by the valve spring.

Finally, the orifice in the valve member 28 is aligned with the orifice connected to the pipe 30 so that the shut down ports of the back up metering valve 3 are connected to the low pressure outlet.

The fuel control system thus provides very rapid bumpless change over from normal operation to back up operation.

If it is required to revert from the back up mode to the normal mode, then the start and change over torque motor 31 is de-energised so that its armature uncovers the orifice connected to the pipe 33. This pipe therefore vents to the low pressure outlet and the spring 29 returns the valve member 28 of the pilot change over valve 21 rapidly to its normal position. The pipe 27 is therefore vented to the low pressure outlet so that the valve member 25 returns relatively slowly to the position shown in Figure 1. The valve member 28 also connects the main torque motor servo return to the low pressure outlet and shuts off the connection between the back up metering valve shut down ports and the low pressure outlet.

As the valve member 25 moves downwardly, it first closes off the connection between the pipe 35 and the low pressure outlet so that the main torque motor 24 can control the servo pressures in the servo

chambers of the main metering valve 18 to position the main metering valve member correctly before the back up metering valve bypass port 15 begins opening. The bypass change over valve 16 then opens the port so as to bypass the metering orifice of the back up metering valve 3. The back up pressure drop spill valve 4 closes and the main pressure drop spill valve 17 resumes control of the pressure drop across the main metering valve 18.

Thus, normal operation of the fuel control system resumes and fuel is metered by the main metering valve 18 controlled by the main torque motor 24. The back up torque motor 10 is controlled so that the back up metering valve 3 tracks the main metering valve 18 so as to be ready for rapid transition to the back up mode if selected.

In order to shut down the engine, the back up mode is first selected and the back up metering valve 3 is then fully closed. The back up metering valve shut down ports thus connect the servo pressure of the back up pressure drop spill valve 4 via the pipe 30 and the pilot change over valve 21 to the low pressure outlet. The back up pressure drop spill valve 4 thus opens to reduce the pressure of fuel supplied to the outlet 22. The pressure raising and shut off valve (not shown) thus closes to shut down the engine.

The start and change over torque motor 31 is energised so as to cover the start orifice so as to provide servo pressure at 36. This is connected to a start valve (not shown) for starting the gas turbine engine. During starting, the pipe from the servo chamber of the main pressure drop spill valve 17 is shut off from the low pressure outlet so that the main metering valve 18 controls the supply of fuel.

In an alternative arrangement (not shown), the back up metering valve may be arranged in series downstream of the main metering valve.

CLAIMS

1. A fuel control system for a gas turbine engine, comprising:

a main metering valve for controlling fuel supply to the engine during a first mode of operation;

a back-up metering valve in series with the main metering valve for controlling fuel supply to the engine during a second mode of operation, the back-up metering valve being arranged to track the main metering valve during the first mode of operation; and

changeover means for bypassing the back-up metering valve during the first mode of operation and for connecting the back-up metering valve with the main metering valve during the second mode of operation.

2. A system as claimed in Claim 1, wherein the changeover means is arranged to inhibit the main metering valve from changing the supply of fuel during a transition from the first mode of operation to the second mode of operation.

3. A system as claimed in Claim 1 or Claim 2, wherein the changeover means is arranged to cause the main metering valve to open fully after the back-up metering valve has been connected in series during the second mode of operation.

4. A system as claimed in any one of the preceding claims, wherein during a transition from the second mode of operation to the first mode of operation, the changeover means is arranged to cause the main metering valve to adopt the same setting as the back-up metering valve before bypassing the back-up metering valve.

5. A system as claimed in any one of the preceding claims, wherein the first mode of operation corresponds to normal operation.

6. A system as claimed in Claim 5, wherein normal operation corresponds to automatic control of fuelling.

7. A system as claimed in Claim 5, wherein normal operation corresponds to control in accordance with an engine control management system.

8. A system as claimed in Claim 7, wherein the engine control or management system uses data processing to provide optimised fuel control.

9. A system as claimed in any one of the preceding claims, wherein the second mode of operation corresponds to back-up mode.

10. A system as claimed in Claim 9, wherein the back-up mode is arranged to maintain control in the event of a fault or failure in the main metering valve.

11. A system as claimed in Claim 9, when dependent on Claim 6 or Claim 7, wherein the back-up mode is arranged to maintain control in the event of a fault or failure in the engine control system.

12. A fuel control system substantially as hereinbefore described with reference to Figure 1 or Figure 2.

The Patent Office

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Application N : GB 9508770.6 **Examiner:** C B VOSPER
Claims searched: 1-12 **Date of search:** 12 July 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): F1G(GNA,GNB,GNC,GND,GNX)

Int Cl (Ed.6): F02C 9/00,9/26,9/32,9/38,9/46

Other: ONLINE WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB2003234A	UNITED (page 1, line 93 to 104; page 2, lines 12 to 28; claim 1: shows main and back-up valves in series, and back-up bypass)	1
A	EP0436513A1	LUCAS (col. 2, line 21 et seq.)	1
Y	EP0399437A2	COLT (claim 1: shows main and back-up valves in series, and bypass)	1
A	EP0065888A1	AVIATION (claim 1)(US equivalent - US4417440)	1
A	EP0049662A1	BENDIX (claim 1; page 4, line 35 et seq.)	1
A	EP0037786A2	BENDIX (page 4, line 35 et seq.)	1
Y	US4368618	BENDIX (col. 1, line 50 to col. 2, line 65; col. 6, lines 32-39: appears to show tracking features)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.